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GAS AND OIL ENGINE MANAGEMENT

GAS AND OIL ENGINE MANAGEMENT

A Practical Guide for Users and Attendants

BEING NOTES ON
SELECTION, CONSTRUCTION, AND MANAGEMENT

BY

M. POWIS BALE, M.I.Mech.E. A.M.I.C.E.

AUTHOR OF "A HANDBOOK FOR STEAM USERS," "WOODWORKING MACHINERY,"
"STONEWORKING MACHINERY," ETC.



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PREFACE

THE very large measure of success that has attended the Author's "Handbook for Steam Users,"* and another small work of his on "Steam and Machinery Management,"† has induced him to write the following pages on similar lines, and he trusts they may prove of service to those using fixed Gas or Oil Engines.

The principle, or cycle, on which gas and oil engines work is at present almost entirely the same, but as their constructional details vary considerably, the Author wishes it to be distinctly understood that the instructions given must be considered as general, and not arbitrary. The matter has been condensed as much as possible, and arranged in the form of paragraphs for easy reference.

The Author having had a gas engine in use in his

* Longmans, Green, & Co.

† Crosby Lockwood & Son.

workshops for some fifteen years, and having erected many others, much of the matter given has been deduced from everyday practice. At the same time, he begs to tender his thanks to the leading makers of gas and oil engines for the information respecting their engines freely placed at his disposal.

16 & 17, APPOLD STREET,
LONDON, E.C.

October, 1903.

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GAS AND OIL ENGINE MANAGEMENT

CHAPTER I

SELECTING AND FIXING A GAS ENGINE

Constructional details—Fixing a gas engine—Cooling water supply—Gas supply—Calorific value of coal gas—The calorific value of Dowson gas—The calorific value of Mond gas—The calorific value of blast-furnace gas—The calorific value of water gas—British thermal unit (B.T.U.)—Ignition temperature—Pressure in gas engines—Size of gas meter—Gas-meter readings and their reduction to a standard of pressure and temperature—Bore of gas pipe—Consumption of coal gas in gas engines—Producer gas.

ALTHOUGH the principle or cycle on which gas and oil engines work is now almost entirely the same, their constructional details vary considerably; the writer therefore wishes it to be distinctly understood that the instructions given must be considered as general and not arbitrary.

It need hardly be said the selection of an engine

of a type and construction exactly adapted to the nature of the duty it has to perform is a matter of critical importance with regard to its satisfactory and economical working; and unless this selection is judiciously carried out heavy loss and annoyance may result.

Each case should therefore be judged on its merits; the chief points to be considered are: (1) the nature and calorific value of the gas to be used; (2) the speed, duty, and power required of the engine. But as the design and details of construction would necessarily vary considerably, an untechnical reader would do well to take the advice of a competent engineer before deciding for himself, as we cannot do more here than give a few general hints.

An engine of a size showing a fair margin of surplus power over the work to be done should be chosen, as, unlike a steam engine, it cannot be pressed beyond its ordinary full working load when extra power is required; and no gas or oil engine should be run at its maximum horse-power for lengthened periods.

As a rule, gas engines are well made, but as some poor ones are on the market, a few points to be desired in the construction of an efficient engine may not be out of place.

Constructional Details.—An ideal gas or oil engine should embody simplicity of construction, combined with high-class workmanship, efficiency, economy, certainty of action, uniformity of speed and adaptability to varied and suddenly applied loads.

The motive power of gas and most oil engines being produced by sudden explosions to successfully take up the strains set up, a heavier frame, cylinder, flywheel, crank-shaft, etc., are required than in a steam engine of equal power; engines of light construction should therefore be avoided.

The main frame should be of massive construction with an extended base, which in the smaller engines is generally brought down to the floor line.

The cylinder usually overhangs, but to increase their rigidity, engines have now been introduced in which the cylinder is bolted to, and supported by, the main frame, which is extended.

The cylinder should be fitted with a hard-metal liner, and all ports and passages should be as straight and free as possible; and, to allow of equal expansion, sudden changes in the thickness of the metal should be avoided.

The combustion chamber is formed by some makers in the cylinder ends and by others in a separate chamber, and advantages can be claimed for each system.

Built-up pistons with junk rings and covers are to be preferred to solid trunk pistons and snap rings, as they can be more easily adjusted, cleaned, or renewed.

The pistons should be long ; shallow pistons should be avoided, as they are more liable to seize at their opposite top and bottom edges, and be thrown out of truth than a long one. A long piston, too, is steadier at high speeds, holds lubrication better, and is less liable to leak. Other things being equal, it will also work with less friction than a short piston. The piston should have at least four rings. Excess of clearance space in the combustion chamber, valve chests, ports, etc., should be avoided. The piston cross-head pins should be made of the finest cast steel of large diameter, and be a dead-true fit.

It is of great importance that the piston and cylinder be a dead-true fit, and some makers secure this by grinding them in ; and especial care should also be taken with the water-jacketting arrangements, so that all parts of the cylinder subject to the heat of the explosions are properly cooled, or trouble may arise.

The area of the exhaust ports should be as large as possible to allow of the instant escape of the exhaust and avoidance of back pressure.

In large gas engines, where a trunk piston is

employed, considerable trouble often occurs through the piston when hot expanding more than the cylinder, consequently the piston rings often cut the cylinder and form ridges, necessitating the more frequent withdrawal of the piston and removal of the ridges.

For large engines, the consensus of opinion is now generally in favour of the employment of a built-up piston with cross-head and guides, in lieu of the trunk piston, and the piston is made adjustable so that it can be readily lined up centrally.

Many forms of governing are used with large engines, including one in which a graduated cut-off is employed, which alters and regulates the mixture of the charge in proportion to the load on the engine, and for which very economical results are claimed.

Two flywheels can be recommended for steady running; at the same time, they equalize the wear on the crank-shaft bearings. They should be carefully turned and balanced, and run perfectly true at full speed. If one wheel is used, it should be of heavy construction and supported by outside bearings.

It is important that the crank shaft be of ample strength; in the best practice, it is made of forged steel cut from solid, and finished bright all over. If the crank shaft be too weak, it will spring with the

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explosions, and give constant trouble when running at full load, which fact was recently verified by the writer in a case in which he was consulted.

A rule followed by some manufacturers is to make the diameter of the crank shaft one half that of the cylinder.

The crank-shaft bearings are usually set at an angle ; they should be heavy, of extended area, and readily adjustable. Outside bearings should be fitted to large engines where the crank shaft overhangs. The connecting-rod bearings are best made of phosphor bronze, and must be adjustable for wear.

The valves should be of ample area and short lift, and be arranged so that they can be readily inspected and adjusted, have a positive motion and with as few packed joints as possible. The writer prefers them fitted at the back end of the cylinder.

The valve gear should be free from complication, and all gear wheels machine cut. The governor gear should be direct and free from complication, be readily adjustable as to speed, and sensitive to suddenly applied or other loads. Centrifugal governors are now usually worked by means of skew-gear wheels, which are preferable to ordinary bevel wheels, as they are stronger, more sensitive, and steadier in their running, with less liability to wear.

All cams, rollers, pins, etc., should be case-hardened.

With the object of securing extreme sensitiveness, some makers now mount their governors on ball-bearings.

Timing valves should be fitted to all but the smallest engines, and mechanically operated lubricators to the cylinder, crank, and cross-head pins.

Large engines should be provided with a good safety starting gear, an anti-fluctuator to regulate the gas pressure, and a silencer to deaden the noise of the exhaust. If the gas is dirty, some form of "scavenging" will be necessary.

To secure increased steadiness in running and freedom from vibration, in addition to using two flywheels, large engines are often mechanically balanced by counterweights fitted to the crank shaft, or by the employment of double cylinders.

For very large power, engines with two cylinders placed opposite each other and working on the same crank pin or shaft can be recommended. With the object of equalizing the heat and expansion of the piston of very large engines when running at either full or half-load, some makers now water-jacket the piston.

Should the engine be required to run at a high speed, the bearing surfaces should be longer and of greater area than in slower-running engines, and the materials and workmanship must be of the first order. ✓

Whatever engine be selected, a full detailed specification should be obtained by the user from the maker, with his guarantee as to *brake* horse-power it will give out with gas of a certain calorific value, and that it will work at its full speed and power without excessive vibration, and will run steadily under suddenly applied loads.

It may be stated generally that for economical running an engine should work at its full safe-working load and with high compression, but not constantly at its maximum effective horse-power.

Fixing a Gas Engine.—The engine should be fixed in a separate, well-lighted room, free from the dust of the manufactory. At least three feet of space should be provided round the engine to enable the driver to get at the flywheel, etc., and it should be arranged to give a straight and fairly long drive.

Stone blocks, brickwork, or concrete are suitable for foundations, and drawings showing the sizes necessary are usually furnished by the makers.

If brickwork is used, the bricks should be hard and well burnt and set in good Portland cement; and if concrete be employed a mixture of one part best Portland cement to six of good ballast or four of broken stone and two of sharp sand will be suitable.

The foundation bolts should be long and pass entirely through the masonry, and afterwards be cemented into their places. This can be effectively done by placing drain pipes round the bolts and afterwards withdrawing them and pouring in cement.

Should the vibration of the engine working be likely to prove an annoyance it can be modified to a certain extent by placing thick sheets of felt or cocoa-nut matting between the engine bed and the foundation. Care should be taken that the engine is made dead level in all directions and square to the driven pulley.

As the foundations shrink in drying, the bolts should be tightened up occasionally for a few weeks. If the engine has to be placed on an upper floor there is less liability of the joists springing if it be fixed in a corner.

When the engine is lowered on to its foundation it should be wedged up and carefully grouted with liquid cement to ensure a solid foundation.

Should there be much vibration when the engine is started, it will probably arise from improper or insufficient foundations, or from insufficient balancing of the reciprocating parts of the engine.

In erecting an engine, all the bearing surfaces should be thoroughly cleaned and lubricated, and the engine be allowed to run light for an hour or two.

Before starting, all ports, passages, and pipes should be carefully cleaned from grit and sand.

Cooling Water Supply.—The cooling water supply must be constant and ample, and should by preference be taken from the main, and the supply regulated by a ball-cock and waste pipe.

The water pipes for cooling should be of ample capacity, and the one connecting the top of the cylinder jacket with the upper part of the tank should always be arranged with a continually rising column, be as short as possible, and any bends necessary should be with a large curve to avoid air lodges.

The return pipes should be about one third larger than the flow. If the cylinder is allowed to get too hot, the power given off is considerably reduced. The reason of this being that the heat expands the gas, consequently the piston does not draw in the same amount as it does when the cylinder is cool.

If the mean temperature of the cylinder is allowed to exceed about 400° Fahr. its lubrication will be difficult, and if the cylinder is found much hotter than the cooling water in the tank, its circulation is bad from incrustation or what not, and should be seen to.

Never work the engine without water in the cylinder jacket, and always keep the level of the

water in the tank two or three inches above the top water pipe.

The amount of the cooling water supply which is necessary increases with the heaviness of the load on the engine, and should be regulated accordingly.

The cooling water supply should enter near the exhaust port and leave it at the highest point of the jacket.

The cooling water required in the circulating tank averages from 25 gals. to 30 gals. per indicated horsepower, and the quantity in the water jacket to keep the cylinder cool under ordinary working conditions about 5 gals. per I.H.P.

The temperature of the cooling water from cylinder should never be hotter than, say, 140° Fahr., and if the load is constant and heavy this should be reduced, but be never less than 100° Fahr.

If a series of tanks are employed, the connecting pipes should be arranged so that the water is drawn from the bottom of the first tank to the top of the next in the direction of the circulation.

In frosty weather a gas jet should be kept burning underneath the cylinder to prevent the water freezing during the night.

The water tanks should be fixed above the level of the engine, as the higher the tanks the better the circulation through the cylinder jacket ; at the same

time a sharp bend on the up-take pipe, from the top of the cylinder jacket to the top of the tank is avoided.

The cock at the bottom of the tanks should be a "straight-through" cock, and a cock for draining the jacket must also be fitted. All joints should be very carefully made, a leakage from the water jacket to the cylinder will give serious trouble.

Gas Supply.—It is important that the gas supply should be constant, and not be subject to much variation in pressure or quality. Should the supply, however, be subject to considerable variations of pressure, as is sometimes the case, either an anti-fluctuator should be fitted to the gas bag, or a gas governor in the gas main, between the meter and the gas bag.

To secure the proper proportions of gas and the steady running of the engine, the regulator should be adjusted for the lowest pressure of gas the engine will have to work with.

The gas supply for the ignition tube should not be taken from the engine supply, but have a separate pipe to itself from another meter, as the sucking action of the engine in the former case often prevents a steady heat being given to the ignition tube, consequently "mis-fires" may arise, with a corresponding reduction in the speed of the engine.

It is important that the meter and gas supply pipes are not cramped in size, or the power and speed of the engine will be reduced. We give elsewhere the rules which generally obtain for calculating these for town gas. The rubber gas bag should be fixed near the engine.

In regulating the gas supply it should always be borne in mind that the air admitted to the cylinder will only allow of a certain quantity of gas being burnt, and any gas admitted in excess of this is consequently unconsumed, and is carried into the exhaust and wasted.

The pressure at which the gas is delivered to the engine should be ascertained and the supply exactly regulated accordingly. In starting the engine, if the gas supply is too rich it will not ignite, and the engine will slow down and stop.

It is important that the gas used is of uniform quality, and that there is uniformity also in the charge. If the charge of gas and air is thoroughly mixed there is less chance of "mis-fires." With this object in view, a mixing box is sometimes employed, in which is introduced a bundle of fine wire through which the charge passes ; this has the desired effect, but with dirty gas the wire will require frequent cleaning.

Again, if the engine is overloaded, the chance of "mis-fires" is increased, also if the spring of the

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admission or exhaust valve becomes weak. In the case of electric ignition, this may arise also from loose connection, or if the contact breaker or sparking plug be out of order.

The gas and exhaust piping should be of ample size, and as short and direct as possible, and free from sharp bends. A blow-off cock should be fitted at the lowest point of the gas piping near the engine to carry off any water or gas diluted with air that may accumulate. The exhaust box should be kept clear of woodwork and fixed on a stone or brickwork foundation, and where it can be readily examined and cleaned. Coal or producer gas possessing not less than 100 British thermal units per cubic foot can be used, and up to 700 B.T.U.

Calorific Value of Coal Gas.—The calorific value of good coal gas is about 650 B.T.U. per cubic foot.

The Calorific Value of Dowson Gas averages about 160 B.T.U. per cubic foot, and requires about $1\frac{1}{2}$ times its volume of air for complete combustion.

The Calorific Value of Mond Gas averages about 150 B.T.U. per cubic foot, and requires about $1\frac{1}{2}$ times its volume of air for complete combustion.

The Calorific Value of Blast - furnace Gas averages about 100 B.T.U. per cubic foot, and requires about $1\frac{1}{4}$ times its volume of air for complete combustion.

The Calorific Value of Water Gas averages about 400 B.T.U. per cubic foot.

British Thermal Unit (B.T.U.) is the quantity of heat required to raise one pound of pure water from 32° to 33° Fahr.

Ignition Temperature.—The ignition temperature in gas engines is about 3000° Cent.

Pressure in Gas Engines.—The sudden pressure developed in a gas-engine cylinder is stated at from 300 to 450 lbs. per square inch.

Size of Gas Meter.—The rule generally employed for finding the size of meter (dry) necessary for supplying a gas engine is as follows:—Size of meter (counted in lights) = $3.4 \times \text{B.H.P.} + 5$. The 5 may be neglected in getting the size for a large engine. The result gives the size of meter measured in lights, estimated by the number of lights the meter is intended to supply.

Gas Meter Readings and their Reduction to a Standard of Pressure and Temperature:—

Let V = volume measured by meter.

P = absolute pressure of gas in pounds per square inch.

T = measured temperature of gas in degrees Fahr.

X = volume of gas reduced to 32° Fahr., and 14.7 lbs. per square inch.

$$\text{Then } X = V \cdot \frac{P}{14.7} \cdot \frac{493}{T + 461}$$

Bore of Gas Pipe.—Multiply meter, size as above determined, by 0.008, and add 0.75. The result is the size in inches.

Consumption of Coal Gas in Gas Engines.—The average consumption of town gas in an engine of first-class construction is from 18 cubic feet to 25 cubic feet per B.H.P. per hour. Small engines, however, consume more in proportion than larger ones.

Producer Gas.—As distinguishing it from ordinary coal gas, what is known as producer gas is now largely used in gas engines—and for large engines especially—when made under favourable conditions, undoubtedly

a considerable economy is thus effected, as the cost is usually only about one halfpenny per B.H.P., whilst with ordinary coal gas at 2s. 6d. per thousand feet, it would amount to about 1d. for the same power.

Producer gas has usually been made from Anthracite coal or coke (Dowson), but latterly a process has been introduced in which a superior gas has been obtained from a bituminous coal (Mond); at the same time, by this process, a large amount of sulphate of ammonia is recovered from the fuel, thus further reducing the cost of the gas.

If producer gas be used, it is very important that its calorific value be ascertained, so that the maker of the engine can arrange the correct amount of compression, mixture of gas and air, point and method of ignition, etc.

Blast-furnace gas for working large engines has latterly come considerably into use. It is of low calorific value, and requires a high degree of compression, but as it is a waste product in most iron-works, there is little doubt that its use will be largely extended in the near future.

CHAPTER II

PRINCIPLE OF WORKING, ETC.

Principle of working—Efficiency of a gas engine—Suction—Compression—Combustion and expansion—Exhaust—Silencer—Scavenging—Self-starters—Starting and stopping a gas engine—Guarding gas engines.

As these pages may fall into the hands of users, students, and others who are unacquainted with the principles in which gas and oil engines work, it may be as well, in the first place, to briefly notice the matter.

Principle of Working.—The great majority of engines are of the single-acting type, the power being applied only at one end of the piston, the cylinder being open at the other, and are built on what is known as the Beau de Roches or “Otto” cycle of operations. These operations are four: (1) suction, (2) compression, (3) combustion and expansion, (4) exhaust.

(1) The suction stroke is the first out-stroke of

the piston, which draws into the cylinder a mixture of air and gas.

(2) In the ensuing in-stroke of the piston the mixture of air and gas is compressed in a space at the back-end of the cylinder.

(3) As the crank is passing the dead centre on the commencement of the second out-stroke, the mixture of gas and air is fired, and the piston pushed forward by the pressure arising from its combustion.

(4) The cycle of operations is completed by the second in-stroke, during which the products of combustion are exhausted to the atmosphere.

It will be seen, therefore, that an explosion takes place, and an impetus is given to the piston once in every four strokes—or two revolutions—of the engine.

To enable this cycle of operations to take place at the correct moment, four valves are usually fitted, viz. air, gas, ignition, and exhaust valves. These are arranged to act automatically at certain fixed periods, and the successful working of the engine depends largely on their construction, condition, and correct timing.

Efficiency of a Gas Engine.—Speaking generally, the efficiency of a gas engine may be said to depend, in the first place, on : (1) its design, workmanship,

erection, condition, and proper lubrication, and afterwards on :—

- (2) The proper mixture of air and gas.
- (3) The correct amount of compression.
- (4) The correct point, time, and ease of ignition.
- (5) The duration of combustion and its completeness.
- (6) The rapidity and amount of expansion.
- (7) Efficient governing and exhaust.

If any doubts exist as to the engine giving out its proper power, it should be both indicated and tested under the brake.

← **Suction.**—The admission of gas into the cylinder or combustion chamber is usually effected through the medium of a lift-valve connected to, and its action regulated by, the governor gear. The air entering at the same time through a separate valve into the combustion chamber and becoming mixed with the gas, forms the explosive charge.

It will be seen, therefore, that the proper condition and regulation of these valves play an important part in the economical working of the engine. For instance, if too weak a charge is admitted, it will not explode, and the gas is wasted, or may be burnt further on in the exhaust; or if too rich a charge is admitted, pre-ignitions are likely to occur.

Again, if the gas-supply cock is not open sufficiently, a weak mixture will result, or if the air valve leaks, or air has got into the gas-supply pipe, a faulty suction will ensue, and sometimes the engine will not start. If the engine has stood some time, the gas pipe should be blown out before starting.

Care should be taken that the air supply is not dusty and the pipes free from grit. If the engine is fixed in a dusty situation, the air supply should be made to pass through fine gauze.

Compression.—It is generally admitted that high, but not excessive, compression of the charge, combined with complete combustion and expansion, are the most important factors in the economical working of gas engines.

With high compression the charge of gas and air becomes more thoroughly mixed together, is more rapidly fired and with greater certainty, consequently the combustion is more complete, and the force arising from the explosion of the charge greater.

By compression, a smaller-sized cylinder is required to give out the same power, and a weaker charge can be fired. If, however, the compression be too great pre-ignition will occur, and a violent shock given when the charge is exploded.

If the engine loses its compression, it usually arises

from the defective condition of the exhaust or air valves, joints, or piston rings. The valves should be taken out and the joints examined, and see if the valves bed properly in their seats. If not, they should be carefully ground in with fine emery powder and oil, the emery grit being wiped away with paraffin.

If the valve spindles are stuck, they should be eased where they bear with a smooth file.

It is, of course, highly important that the amount of compression is adjusted to suit the nature of the gas or oil used.

x **Combustion and Expansion.**—The combustion of a charge depends largely on: (1) its temperature; (2) its richness, or the proportions of gas and air, and their complete admixture; (3) on the amount of compression.

The time of combustion is not affected by the speed of the engine; but it is retarded rapidly by increased expansion. To secure more perfect combustion and the best results, there seems to be little doubt that an important factor is that the charge of gas and air be thoroughly mixed before firing, that the compression is perfect, and that the charge is not fouled owing to defects in the exhaust.

As regards expansion to secure the best working

effect, it is generally concluded it should take place near the commencement of the stroke—to allow the full volume of the cylinder being utilized—and be both as rapid and prolonged as possible.

Exhaust.—It is important that the products of combustion are got rid of as rapidly as possible, and the cylinder and passages kept clean and free, and with this object several methods of “scavenging” have been introduced.

The exhaust pipe should be of iron, straight, of large diameter, and never less than the opening of the valve; in fact, if made, say one-fifth larger, it is better. It should not be arranged in a horizontal line, or turned into a chimney, and sharp bends should be avoided.

The pipe and exhaust box should be kept clear from woodwork, and be cleaned, and any water drawn off periodically to avoid back-pressure and oxidation.

The exhaust box should always be fitted at a lower level than the cylinder. The noise of the exhaust should be sharp and decisive; if it is irregular, weak, or wheezy, the engine is not working properly. This may arise from various causes, such as a short supply of gas, back-pressure, etc.

The exhaust valve is usually arranged to open

at a point in the exhaust stroke that will reduce the pressure in the cylinder to about that of the atmosphere when the stroke is completed when it closes. If the speed of the engine is increasing, it should open earlier, and later if decreased.

Should the exhaust-valve spring become weak, or the valve seat be worn, it will show itself by vibration of the valve, loss of compression, and explosions in the exhaust pipe.

Should there be a squeak in the exhaust valve, it may arise from the valve tilting and the friction of the valve stem against the guide. The valve stem should be lubricated with plumbago.

Should smoke or much smell, showing unburnt gases, come from the exhaust, it may be concluded that the engine is not working properly.

It is generally concluded that the velocity of the burnt products entering the exhaust should not exceed about eighty feet per second.

Silencer.—The most general form of silencer used is a box or chamber filled with gravel or plates, through which the exhaust gases pass on their way to the open air. The use of a silencer causes a certain amount of back-pressure on the piston, but this is considerably increased if the silencer is too small or the exhaust pipe, or the gravel in the

silencer is allowed to become foul with residue. The silencer and pipe should therefore be cleaned periodically, the gravel either renewed or washed and riddled occasionally, and the silencer be of ample area.

A rule often used to determine the volume of a silencer is $3\frac{1}{2}$ times the product of the square of the piston diameter multiplied by the stroke.

To obviate any noise from the air suction, a pipe of rather larger diameter than the air inlet can be carried outside the building ; it should be as free as possible from bends, and its end protected by a perforated cap, which should be kept clean.

Scavenging.—Where dirty or poor gas has to be used, to avoid the constant clogging of the cylinder and valves with residue and consequent pre-ignitions and back-firing, and general disarrangement of the engine, some form of “scavenging” or clearing away of the burnt products is necessary.

A plan sometimes pursued is to use an idle stroke for this purpose, a charge of gas being cut out by the governor acting on the admission valve and admitting only a charge of pure air for one stroke on completion of the exhaust stroke.

For “scavenging” purposes, another plan is to set valves so that the air valve opens during the latter

part of the exhaust stroke, and delaying the closing of the exhaust valve till part of the suction stroke has been made, but this plan, owing chiefly to accumulation of residue through reduction of pressure in the exhaust, has not been entirely successful.

A very effective "scavenging" arrangement is one in which two pistons are employed. These are connected together in the same line, and one receives the impulse from the explosion of the charge, whilst the other acts as an air pump.

By the aid of suitable mechanism part of the air drawn by the pump is entrapped between the pistons and slightly compressed, and when the exhaust stroke has released the pressure in the combustion chamber, the pump piston follows, and sweeps a volume of air through the combustion chamber into the exhaust, and effectively clears it of burnt products.

Another method of "scavenging" which has been introduced consists in attaching a long, straight pipe on to the ordinary exhaust pipe, and it is claimed for this arrangement that, owing to the high velocity at which the exhaust gases pass along the pipe, a partial vacuum is created in the engine cylinder, which, being destroyed by the entrance of new air, assists in clearing the combustion chamber of residue.

The writer's experience is in favour of a positive "scavenging" stroke, although an idle stroke admits a

charge of air which carries away a certain amount of heat from the cylinder walls, but the cylinder being cleared of burnt gases the next explosion is stronger, as the new charge is not diluted by the remains of the old.

Self-starters.—Owing to the difficulty of starting large engines by hand, self-starters have come considerably into use for engines over, say, 12 H.P., and a great variety of methods have been introduced. Compressed-air starters are simple and convenient, and consist chiefly of a hand or power air pump, which forces air under pressure into a storage tank.

The air tank is connected with the cylinder, and the flywheel being turned till the engine is in a position to start, viz. when the crank is just above half-centre, the compressed-air valve is then opened to its full extent, and closed as the piston approaches the end of its stroke. This operation being repeated once or twice, if necessary, sets the engine in motion.

A number of arrangements are in use in which charges of gas and air are admitted or forced into the cylinder, and exploded by a separate and special igniter, the operation being repeated till the ordinary ignition apparatus comes into operation. Waste gases stored by the engine itself under pressure in a receiver, are also used.

Starting and Stopping a Gas Engine.—To avoid mistakes and confusion in starting or stopping an engine, a regular routine should be observed, such as the following :—

(1) Oil all the working parts, and see that the valves and governor gear are clean and free ; (2) examine water-cooling supply, and open waste cocks in gas and exhaust pipes, and release any condensed water ; (3) light the ignition flame ; (4) open cock of gas valve box on engine ; (5) put in position the starting apparatus, if one is fitted ; (6) when the ignition tube is red hot open the gas cock to supply bag ; (7) if no starting apparatus is fitted, turn the flywheel smartly round by hand in the direction it runs till the engine starts, but do not use the foot for this purpose ; (8) turn gas supply cock gradually full on ; (9) release starting apparatus ; (10) and pass belt gradually on to the fast driving pulley.

Before starting the engine see that the ignition tube is properly heated to a bright red, and the Bunsen burner is in good order and gives a clear, smokeless and even flame.

The gas bag should be filled with gas, and then the supply cock gradually closed until the engine commenced to run, when it can be turned full on. The admission of the right amount of gas for starting can be ascertained after a few trials ; if either too much

or too little is admitted, the engine will be difficult to start. m

↙ In stopping (1) close cock of gas-valve box on engine ; (2) close gas cock from meter to gas bag ; (3) throw off driving belt ; (4) close gas cock of Bunsen burner supply ; (5) close cock of cooling water supply, and run off water from the cylinder jacket if the weather be frosty ; (6) let the engine rest with crank at the bottom centre of the compression stroke, as all valves should then be closed.

If the engine has not to be restarted for some days, it is a good plan to turn off the oil supply to the cylinder for a short period before stopping, as what oil remains will be burnt out, and there is less liability to gumming.

Guarding Gas Engines.—It is now compulsory, under the Factory Act, that the moving parts of gas engines are carefully guarded. What is required are guards that, whilst protecting the attendant, are light and readily removed for oiling, etc.

The writer has found nothing better for protecting the fly-wheel, crank shaft, etc., than wire guards mounted in wrought-iron frames.

To prevent the attendant neglecting those bearings that are not automatically lubricated, lubricators are sometimes placed outside the guards, and connected

to the bearings by pipes. The guard should be continued three parts round the flywheel, and the main-belt drive be also fenced.

In the case of very large engines, many of the guards are fixed permanently with gates where required for lubricating, etc.

A guard rail should also protect the engine from casual visitors.

CHAPTER III

FAILURES AND DEFECTS

Failures of gas engines—Mixture of gas and air—Defective water circulation or insufficient cooling of the cylinder—Leakage of the piston—Leakage of the valves—Improper or insufficient lubrication—Governor gear in a defective condition—Ignition valve or gas supply defective—Back pressure from fouling of the exhaust—Ignition apparatus worn or defective—Imperfect compression or combustion—“Mis-fires,” “back-firing,” etc.—Explosion in air-pipe—Point of ignition wrong—Driving at too short centres—Repairs to gas engines—Leaks in water-jacket—Cause of smoke from cylinder—Engine slowing down—Weak explosions—To secure steady running in gas and oil engines.

Failures of Gas Engines.—Some of the chief causes of failures and stopping of gas engines may be set down as follows, but practical users will doubtless be readily able to add to the number :—

- (1) Bad design or construction of the engine ;
- (2) improper mixture of gas and air ; (3) defective water circulation or insufficient cooling of the cylinder ;
- (4) leakage of the piston ; (5) leakage of the valves or valve joints ; (6) improper or insufficient lubrication ; (7) governor gear defective ; (8) ignition valve,

tube, or gas supply defective ; (9) back pressure from fouling of the exhaust with residue or water ; (10) ignition apparatus worn or defective ; (11) imperfect compression or combustion ; (12) air in gas supply pipe ; increased or decreased pressure of gas, etc. ; (13) "pre-ignitions," "mis-fires," "back-firing," etc. ; (14) point of ignition wrong ; (15) driving at too short centres.

Mixture of Gas and Air.—A considerable loss of power through mis-fires, etc., is often caused through the use of an imperfect mixture of gas and air. No hard-and-fast rule as to exact proportions can, however, be laid down, as it all hinges on the calorific value or richness of the gas used, which depends largely on the nature of the coal from which it is produced.

As the calorific value of coal and the various producer gases vary considerably, the absolutely correct mixture of gas and air necessary to secure the best results cannot be ascertained unless this value is known.

The effective and correct mixing of gas and air is a matter of great importance in the economical working of the engine.

With a rich gas of a high calorific value, a well-mixed charge can be obtained without much trouble

but with gas of a low calorific value, where a much greater volume is required to do the same work, it is not so easy a matter, and should the charge be insufficiently mixed, a proportion of gas is left unconsumed and carried into the exhaust and lost.

As regards the proportions of gas and air in common use, given a good average town gas, about ten volumes of air to one of gas may be taken as a standard. Producer gas, on the other hand, usually requires slightly more air than its own volume for its combustion.

Some engines are fitted with pet cocks, communicating with the ignition chamber, and the correctness of the composition of the mixture may be fairly judged by the colour of the flame when ignited. If it is a deep blue tending to violet, it is about right, but if it shows red or orange it is too rich with gas, and if a very pale blue it is too weak.

Defective Water Circulation or Insufficient Cooling of the Cylinder.—The tanks and connecting pipes should be of ample capacity, and the circulating tanks be capable of holding about 28 gallons per I.H.P., or say, 70 gallons per B.H.P., of the engine. If the tanks are in a hot room, this quantity of water can be increased.

The working temperatures are usually about

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60° inlet, and 140° outlet. Keep the connecting pipes, etc., free from incrustation.

If the water forms a hard deposit, a little tannate of soda should be added to it occasionally, but if soft or rain water can be obtained it is to be preferred.

Leakage of the Piston.—To obtain effective compression and, consequently, good results in a gas engine, it need hardly be said that the piston, cylinder, and valves must be kept in first-class condition. If there is a leakage by the piston, a wheezing and knocking sound is often heard, and the gas consumption is largely increased. This trouble may arise from badly fitted or badly worn piston rings; the cylinder scored from insufficient or improper lubrication, or the cylinder worn oval or out of truth, or overheated from insufficient cooling or lubrication.

If the cylinder is worn, there is no remedy for it but rebor-ing.

These defects in the cylinder, combined with worn or dirty valves, are without doubt the chief causes of failure and want of economy in gas engines, and it will pay well to have all the working parts carefully cleaned and adjusted at comparatively short intervals.

If there is trouble in starting, and a leaky piston is suspected, the inlet valve can be lifted by hand once or twice during suction, as this will admit a

larger charge, and consequently give a stronger start.

If loss of compression is suspected, the charge should be compressed by turning the flywheel backwards by hand, and should there be little or no resistance, it may be concluded that something is wrong.

Leakage of the Valves.—This is of common occurrence, and shows itself by the engine giving out little power or stopping altogether. If this fault is suspected, the flywheel should be turned round by hand, and the charge in the cylinder compressed, and if little or no resistance is experienced it may be concluded a serious leakage exists, either in cylinder or valves. If the inlet valve leaks, the unexploded charge, when compressed, will be forced back into the air pipe, and the next charge will be nearly all gas, instead of a mixture of gas and air; consequently, should it burn at all, very little power is given off. This leakage will give a strong smell of gas in the exhaust, and a yellow-red exploding flame.

A leakage in the exhaust valve may occur from the valve being hung up from dirt, its spring too weak, or the valve seat worn. These defects are a fruitful cause of faulty compression, explosions, etc., the mixture escaping during compression through the

leaky valve into the exhaust pipe and box, and when the charge in the cylinder is fired it communicates with and explodes the gas and air in the exhaust.

The exhaust and other valves should, therefore, always be carefully tried before starting. Kerosene can be recommended for lubricating these valve spindles, as it leaves no deposit, or they can be rubbed with stick graphite. If the exhaust valve spring has become too weak the proper proportions of gas and air become altered, and a series of mis-fires are the result.

All valve faces must be kept true and clean, so as to allow of effective closing. If they are dirty or damaged, a thumping noise will be heard.

Improper or Insufficient Lubrication.—It is the reverse of economical to use a poor oil for lubricating purposes, and it is found in practical working that the very best oil, carefully used, is by far the cheapest. Many good oils are now prepared, especially for cylinder lubrication. What is required is a neutral oil or grease that will not readily develop free or fatty acids under the action of heat, or vaporize readily or form much deposit. A mineral oil is usually employed, to which a slight proportion of vegetable or animal oil, or both, is added.

Although vegetable oil readily carbonizes at high

temperatures, it has a tendency to fill up the grooves between the piston and cylinder walls, and make them more airtight. Animal oil, on the other hand, although liable to form fatty acids, improves the lubricating power of the mixture, and does not deposit much carbon.

If an unsuitable oil has been used, and the piston is withdrawn, it will be found covered with a thick rusty-coloured mass of deposit, which often sets hard, and consumes a large amount of power, at the same time damaging the cylinder and piston rings. A good cylinder oil usually leaves a slight blue-grey deposit.

A heavily loaded engine will require an increased amount of lubrication. Gumming usually arises from overheating from bad circulation or insufficiency of the cooling water, insufficient lubrication, or bad or improper oil. Too much lubrication is also bad, as in addition to wasting the oil it often finds its way into the air passages, etc., and clogs the admission and exhaust valves. Oil should not be employed to lubricate the ignition or exhaust valve; fine plumbago is often used for this purpose.

See that the trimmings in lubricators and grooves in bearings are kept in good order, to prevent waste of oil; they should be arranged to supply no more oil than is necessary to keep the bearings cool, and be removed when the engine is standing.

If the cylinder is allowed to get dry, there is little doubt an explosive dust is created, sometimes causing premature ignition ; improper or low-flash lubricants will often have the same effect.

The lubrication on large engines is often forced by pumps or air pressure.

If too much oil is being supplied to the cylinder it can usually be detected by a smoky exhaust which may, however, arise also from imperfect combustion of the charge.

If the engine is working properly, the exhaust should be almost colourless or with a slight blue haze. The oil used should be of the highest flash point obtainable, as the heat in the cylinder—unlike a steam engine—is very dry and intense.

Governor Gear in a Defective Condition.—To secure steady running it is important that the governor gear be kept in first-class order, and when the joints or gear show signs of wear they should be at once seen to.

The lubrication, too, should have careful attention, as, should this be neglected, or the oil used be liable to gum-up, uneven running will be the result ; in fact, the whole gear should be kept in a thoroughly sensitive condition.

Defects can generally be detected by the inter-

mittent or sluggish action of the governor in regulating the engine. The system of governing generally preferred is the one in which the supply of gas is entirely cut out when the speed of the engine rises. With the object of obtaining a uniform mixture, some governors are made to regulate the supply of both gas and air.

Ignition Valve or Gas Supply Defective.—Should the ignition valve become rusted or hung up, a hissing sound is usually given out by the igniter during compression, the ignition flame is drawn in, and an increased noise is heard in the exhaust. If the gas pressure is increased, and the charge becomes too rich in gas, a black smoke is seen in the exhaust, and ignition flame increases. The fitting of an anti-fluctuator to the gas bag will obviate this latter.

If the gas meter is defective from want of water or other cause, it will at once be shown by the emptiness of the gas bag, and if the pressure of gas gets less from any cause it will be noticed the ignition jet gets continually weaker, and, should the defect not be remedied, mis-fires will result.

Back Pressure from Fouling of the Exhaust.—Considerable loss of power may occur from this cause and remain undetected, especially where the

pipes are small or where there are bends in them. If there is much accumulation of water it may run back through the exhaust valve into the cylinder, ignition port, etc., and give considerable trouble. A water cock should in all cases be fitted to the exhaust, and opened periodically, more particularly during the winter, when condensation is largely increased.

Instead of short, sharp pulsations, a fouled exhaust will be long drawn out and irregular, and the cylinder will be dirty, and smoke.

Ignition Apparatus Worn or Defective.—If the ignition apparatus is allowed to get worn and defective, a late ignition of the charge usually takes place, resulting in a loss of power, and producing a loud noise in the cylinder and exhaust.

If the ignition valve is not tight, the jet may readily be blown out through increased pressure after mis-fires.

Imperfect Compression or Combustion.—Imperfect compression arises from worn cylinder or piston rings, overheated cylinder and leaky or dirty valves, and imperfect combustion from improper mixture of gas and air, incorrect firing, and imperfect compression.

“Mis-fires,” “Back-firing,” etc., usually arise from weak mixture of gas and air, valves out of order, improper size or length of tube, or tube not hot enough, etc. The overloading of an engine also has a tendency to produce mis-fires. **“Back-firing,”** from leaky exhaust valve, or from a misfire, the unburnt mixture being carried into the exhaust pipe, and subsequently fired by the flame of the next explosions. Back-firing may be also caused by not opening the gas supply far enough, thus producing a weak mixture, which burns slowly, and fires the next charge, which rushes into the exhaust with a loud report.

With late ignition or **“back-firing,”** there is an incomplete combustion of the charge, consequently there is a higher pressure in the exhaust, and power is lost; at the same time increased strain is put on the exhaust valve gear, and the valve itself becomes heated.

Back-firing is more frequent with gas of a low-ignition temperature.

A **“scavenger”** stroke which allows cool air to pass through the engine every cycle has a tendency to prevent back-firing and pre-ignitions.

Explosions in Air-pipe.—These usually arise from shortness of gas; a weak charge being fired smoulders

in the combustion chamber and exhaust, and mixing with the gas in the next suction stroke, explodes it.

A further loss arises from this explosion, as on the next suction stroke these partly burnt gases enter the combustion chamber, instead of an entirely fresh supply of gas and air, and consequently retard and reduce the power of the next explosion.

Point of Ignition Wrong.—If the charge in the cylinder is not fired at the correct moment the maximum effect of the explosion is not attained, and a constant and sometimes a considerable loss of power may be going on.

If the ignition of the charge is too early, the maximum pressure on the piston is reached before the end of the stroke, and its effect is lessened; or, if the charge is fired too late, it has the same result, as the average pressure on the piston is reduced in proportion.

To get the most powerful impulse it is generally concluded that the charge should be fully fired and the highest pressure reached at the commencement of the expansion stroke.

Driving at too Short Centres.—The writer has known many cases where an engine has been blamed

for not giving out sufficient power, where the trouble has largely arisen through driving at too short centres, and the consequent slipping of the belt.

Short centres should be rigorously avoided, as they mean tight belts, increased slip, increased wear to belt and bearings, and constant trouble.

The driving and driven pulleys, too, should not be of small diameter, should be in proper ratio one to the other, and the bottom side of the belt by preference be the driving side.

Repairs to Gas Engines.—These should, wherever possible, be repaired by their makers, who usually manufacture to gauge, and users may rely that the springs to valves, etc., are of the correct strength, this latter being a very important matter.

The only way to correctly ascertain the behaviour of the gas in the cylinder, and whether from defects the engine is not giving out its proper power, is to have it indicated and tested on the brake, if possible, periodically, and there is not the slightest doubt that it will amply repay users to see that their engines are kept in what may be termed scientific order.

Leaks in Water-jacket.—These may be sometimes stopped by filling the jacket with a solution of

sal-ammoniac and water—say 8 oz. of sal-ammoniac to one gallon of water. Blow-holes may be filled by a cement made of litharge, glycerine, and red lead in equal proportions.

Cause of Smoke from Cylinder.—If black smoke comes from the cylinder, it may arise from (1) leaky piston, (2) over-heating, (3) want of or excessive lubrication, (4) too rich mixture, (5) faulty combustion, (6) faulty ignition.

Engine Slowing Down.—An engine may slow down or stop from a variety of causes, such as (1) overheating of the cylinder, (2) defects in the valves or joints, (3) if overloaded, (4) overheating of bearings, (5) defective ignition, etc., (6) defective compression.

Weak Explosions may be caused from (1) improper mixture, (2) ignition set too late, (3) loss of compression from defective piston, valves, or joints, (4) relief cock open, etc.

To secure Steady Running in Gas and Oil Engines.—To secure a constant speed and steady running, all the working conditions must be kept as uniform as possible.

For example (1) the quantity and temperature of the cylinder jacket-cooling water discharge should not vary, (2) uniformity in the quality and amount of the charge, (3) uniformity in compression and ignition, (4) constant and equal lubrication, (5) free exhaust and uniformity of its temperature, (6) sensitive and steady governing. ✓

CHAPTER IV

VALVES, IGNITION, PISTON RINGS, ETC.

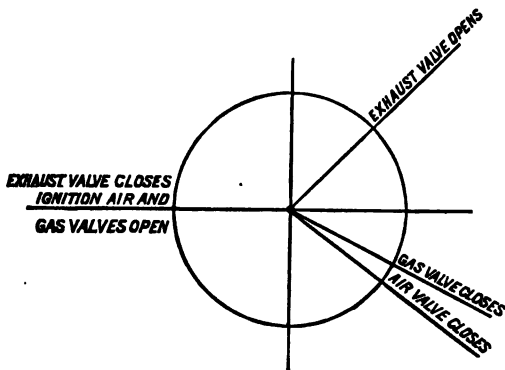
Valves—Setting of valves—Hanging up of valves—Broken and damaged valves—Weak valve springs—Cams and levers for operating valves—Lift of valves—Joints of valves, etc.—Point of ignition—Timing valves—Pre-ignitions—Ignition tubes—Piston rings, etc.—Knocking in the cylinder—Knocking in the engine generally—Governor gear—Classification of various methods of governing—Speed of engine and number of explosions—Piston speed of gas engines—Hot bearings—Hot crank-pin bearings—Examining gas or oil engines—Cleaning a gas or oil engine—Two-cycle gas engines—Gas engines for electric lighting—Compound gas and oil engines—Gas engines using producer gas *v.* Steam engines.

Valves.—Modern gas engines are now usually operated by means of four valves—for air, gas, ignition, and exhaust. These are generally of the conically seated lift type, and should by preference be mechanically operated. They open and close at the various positions of the crank, as shown in the diagram on the next page.

Valves are now largely made of steel, and are of heavy construction, to lessen the liability to heat or

fracture. To prevent heating, some makers water-jacket their valves, and others arrange for a current of air to circulate through them.

The valve spindles should be an easy fit, and the valve spindles and heads made of different materials. Cast-iron valves with steel shanks have recently been strongly recommended by some engineers. The neck



of the valve, which is subjected to considerable strain, should be especially strong.

All valves and gears should be so arranged that they can be readily inspected and repaired. Some makers now construct the exhaust valve seating as part of the cylinder casting, instead of bolting it on, to lessen the liability to heating and breaking of the joint.

The valve area should be ample, with a moderate

lift. In some of the older engines, no doubt, the valves and passages were too constricted, and the lift of the valves too high.

Inlet valves are often made to act by the suction caused by a partial vacuum in the cylinder during the suction stroke, but as this necessitates a certain amount of "wire drawing" and consequent constant loss, mechanically operated valves are undoubtedly to be preferred, there being also no liability to their sticking, as in suction valves.

The mushroom or conical form of lift valve has proved itself to be the best form to use for gas or oil engines, as owing to the absence of rubbing friction their wear is increased, and there is less difficulty of keeping them in order.

Should it be found, however, that a valve has only even been slightly scored from the rapid rush of the hot gases, it should be at once attended to, as the damage is quickly extended and the power of the engine reduced. Should the valve stem leak, the bearing should be reamed out and bushed, or a larger valve stem fitted. All valves should be fitted with loose covers to permit of ready examination.

Setting of Valves.—Users would do well to note that the efficiency and economy of a gas or oil engine depends very largely—as in a steam engine—on the

proper timing and setting of the valves to suit the nature and calorific value of the gas or oil used.

This is, of course, an engineer's question, but one that does not always receive the attention it deserves, and we have known more than one case where a constant and substantial loss has been going on through errors in this connection. In one case this occurred through the exhaust valve opening too late, thus causing a considerable amount of back pressure.

Hanging-up of Valves.—This will occur if the valves are allowed to get dirty, rusty, damaged, overheated, or valve spindle bent.

If the valve springs should become weakened from work, or from being overheated, they should be replaced at once or large loss may occur. All valves should be well lubricated, and not fit their stems too tight, or when heated and expanded they may stick.

Broken and Damaged Valves.—This often happens from poor design of valves, such as insufficient area or too great lift, or weakness of neck of valve, burning, dirt, irregular wear, etc. If the exhaust is throttled from too small a pipe or silencer, or from its being partially filled up with residue, back pressure will arise and cause hammering of the valve, and increase

the liability to fracture. If the exhaust valve is allowed to leak, it will soon be cut out by the hot gases passing through.

Weak Valve Springs.—Should the valve springs become weak they should be at once renewed, or a loss of compression will arise, and the proportions of gas and air be altered, which means a large loss in the force of the explosion.

When valve springs are renewed, it is of the utmost importance that they be of the same strength as the original ones, or the working of the engine will be disarranged. ✓

Cams and Levers for Operating Valves.—The valves of most gas engines have now a positive motion, and are usually mechanically operated through the medium of cams keyed to side shafts.

If the engine is taken to pieces, it is important that a tooth of the gear wheel on the crank shaft and a corresponding tooth of the wheel on the cam shaft should be marked, so that when put together again the same teeth may gear together, and so avoid altering the throw of the cams and consequent timing of the valves.

All cams should be of steel, accurately machined and case-hardened, and the general arrangement of

cams and levers be free from complication, and readily accessible.

Lift of Valves.—Mechanically operated valves should in all cases be lifted sufficiently to give the full area of the valves round the edges. This decides the lift to be one-fourth of the valve diameter.

Automatically operating valves may have a lift of one-eighth of the valve diameter as a maximum. (Fowler).

Joints of Valves, etc.—In running gas engines, the leakage of the valve joints sometimes gives trouble; care should therefore be taken in renewing and keeping them in order, as should even a slight leakage in a cylinder joint occur, the compression and working of the engine is seriously damaged.

To detect a slightly defective joint is sometimes not an easy matter. The usual manner is to compress by hand a charge of air in the cylinder, and try the joints with a light, or, if the leakage is much, it may be heard.

Joint rings are usually made of asbestos, and should be carefully fitted, as a slight blow in the cylinder joints will destroy the compression.

Point of Ignition.—This is without doubt a very

important factor in the working of gas and internal combustion engines generally, as should the charge be ignited too early the maximum pressure will be reached before the end of the stroke, and the piston will thus be retarded and the power reduced, and the friction on the crank pin increased. To avoid a dead blow on the crank pin, it is now generally concluded that the point of ignition should not be on the dead centre, but immediately after the commencement of the out-stroke.

Again, if the charge is fired too late, the average pressure on the piston—and consequently the power—is decreased in proportion. The quality of the charge and other things being equal, the time taken for combustion is unaffected by the speed of the engine; it therefore follows that to ensure perfect combustion with a maximum pressure at the commencement of the expansion stroke, the point of ignition must be earlier, and advance as the speed increases.

To obtain the highest results, the moment of ignition must be adjusted to suit the charge, the compression, and the speed of the engine.

Timing Valves.—To insure ignition at the correct moment, timing valves are now largely fitted to all but the smallest engines. It is important that they

be certain and rapid in action, and easily adjustable, and be kept very clean, and the valve spindle free in its gland.

To obviate the use of timing valves, some makers adopt the plan of automatical firing by means of the compression of the charge, a portion of the mixture being forced into a hot tube, which fires the charge in the cylinder when the right degree of compression has been reached.

Pre-ignitions.—Pre-ignition may arise from a variety of causes—

(1) Too great compression of charge ; (2) by heated deposit or foreign matter in the cylinder ; (3) from slow or incomplete combustion of the former charge, which remains sufficiently heated to fire the new charge before the finish of its compression stroke ; (4) smouldering gases drawn from the exhaust pipe into the combustion chamber ; (5) from over-heating of exhaust valve ; (6) increased gas pressure ; (7) pre-ignitions are also attributed to the use of low-flash oils for lubricating the cylinder ; and (8) too little air in the charge will also cause too rapid firing ; (9) in the case of electric firing from over-heated igniter points, etc.

Ignition Tubes.—Although the firing of the

charge by means of an electric spark largely obtains on the Continent, English practice is hitherto almost entirely in favour of the employment of a heated nickel alloy, porcelain or composition tube for fixed engines, as these have been found to be tolerably certain in their action, fairly durable, can be rapidly heated, and are low in first cost.

To secure effective and equal heating of the tube and prevent it cracking from unequal expansion, several arrangements have been introduced.

The best with which we are acquainted is a combination of tube holder and Bunsen burner, in which the tube is supported at both ends, but is not connected to the cooler metal of the cylinder; unequal heating is therefore avoided.

One drawback to tube ignition arises from its being fixed at the end of a port, and the heating flame blowing out occasionally.

Electric spark firing, on the other hand, can be carried right into the combustion chamber.

Although the cost and complication of mechanism is increased, the range of the igniting spark may be readily altered to suit the varying speed, richness of gas, and conditions under which the engine may be working, and we look for a considerable extension of electric ignition, more particularly in the case of large engines.

The writer can speak in favour of nickel alloy tubes in preference to porcelain, as their longevity under ordinary conditions is much greater.

If the ignition is timed by a valve, which system can be recommended, and is generally used, except for the smallest engines, it should be arranged to open rapidly, and to its full capacity. Care must be taken that the tube is equally heated and kept to a bright red, but not over-heated, or it may burst. The passage to the combustion chamber should be straight and free, and kept clean. Double tube ignition brackets are now sometimes fitted to avoid stoppage in case of one of the tubes bursting.

Tubes should be renewed as soon as they begin to appear defective, which will be shown by irregularity in the firing, as, although the engine may continue working for some time, a considerable loss of gas may be going on.

In putting in a new tube care should be taken that no grit is allowed to get into the passage to the cylinder.

Tubes should be cleaned before lighting the burner, as it adds to their durability.

It is important that the tube be always kept to a bright red heat; should it be allowed to get foul, mis-fires may result. The asbestos lining and joints should also be kept in good order, as, should

they become much worn, the tube will not heat properly.

When it is necessary to put in a new liner to the chimney the asbestos should be damped with water, and fitted tightly into the interior.

The Bunsen burner should be adjusted so as to give a small blue flame entirely round the tube. If too much gas is being used, a smell will come from the chimney. The burner must be kept clean.

If the flame flies back to the holes in the burner it is short of gas.

In small engines timing valves are often omitted, and an open incandescent tube only employed, the ignition being regulated by the size, length, and position of the tube.

Where producer gas is used electric spark ignition, with a readily variable range, is generally preferable to a tube ignition, being usually more certain in its action. It need hardly be said that erratic ignition is a great source of loss in gas and oil engines.

Piston Rings, etc.—One of the chief causes of loss in gas-engine running undoubtedly arises from faulty compression, which is often largely caused by badly designed, fitted, or worn piston rings.

As regards design, many engines are still fitted with ordinary concentric or parallel snap rings, which

must be held to be wrong both in theory and practice, as, no matter how well made the rings may be in the first instance, if they are of equal thickness of metal all round the circle, when they are sprung over the piston they become distorted, and never recover their true cylindrical shape, consequently never fit the walls of the cylinder properly. To obviate this as far as may be in the best practice, rings are now often made thicker in the middle and thinner at the ends.

Calculations have been made to determine the proper thickness of metal at different points of the ring, so as to ensure its being a true circle when in position, but no fixed standard has been established.

Halsey recommends the use of ordinary concentric rings of equal thickness, but turned in the following way, as giving much better results in a simpler manner:—

The ring is made large, and with two lugs on the inside. It is first cut off and faced to thickness, and the gap is then cut out.

The ring is then sprung together by a clamp on the lugs, and strapped to a face plate, or clamped between two flanges, and turned to the true size of the cylinder bore.

When the clamp is taken off the ring expands

again, but not to circular shape, but when put in its place in the cylinder it resumes its circular form or very near it, and is practically a fit all round.

To secure the best results, the ring should be released from the face plate and re-clamped before making the finishing cut.

A new method of making piston rings has recently been introduced, for which several important advantages are claimed. The rings are turned and finished to the correct size of the cylinder in the usual way, and are afterwards automatically hammered on their inside surfaces, to give them the necessary elasticity.

The hammering is made heaviest and a stress is set up diametrically opposite to the ring joint, and the hammering gradually reduced in both directions till the joint is reached.

It is claimed for this process that an absolutely uniform elasticity is set up in the ring, consequently there is an equal pressure all round the cylinder walls, so that the rings wear evenly, and, being of uniform cross-section, there is less liability to scoring or the cylinder wearing oval, as is the case with eccentric rings, where the pressure is not uniform throughout.

Some makers now use nickel cast-iron for piston rings, and liners, and claim for its use a great

superiority in closeness of grain and wearing power over the best brands of cast-iron obtainable.

If nickel cast-iron or steel be used for liners, etc., especial care should be taken with their lubrication, as owing to their smooth surface, the greasy particles are not readily retained.

In fitting in new piston rings it is of importance that they be made a true fit between the interior of the rings and the grooved seating where they are used, as well as between the outside of the rings and the cylinder wall. The fit, however, should not be a tight one in the grooves, or the springing action of the rings will be damaged.

Bad or carbonized oil will also choke the rings and prevent them acting properly. When new rings are compressed into the cylinder care should be taken that the ends of the joints just meet.

Should the rings not be worn much, and it is found necessary to set them out by "pening," great care should be taken in removing them, so as to prevent distortion. When setting out, the ring should receive a series of blows with the ball of the hammer round its entire inside circumference, care being taken that they are in the centre of the ring, of equal strength, and of equal distances apart.

Should these precautions be neglected, the ring

may become twisted, and not fit properly either in the cylinder or at the joints.

Extreme care should be exercised in fitting in new rings. They should have a moderate amount of spring on them, but should never be forced into position so that they bear very hard on the walls of the cylinder.

They should, in all cases, be arranged so that they break joint; that is, that the joints in the rings do not come in a straight line, and they are best placed at the bottom of the cylinder. Slightly worn rings can often be turned round in the cylinder to equalize their wear with advantage.

The ring nearest the combustion chamber will require renewing first. If the cylinder is in good condition, very little expansion on the rings is necessary, but, if it is worn or scored, no amount of setting out will make a tight joint, and friction of working is largely increased.

We have found thin rings, as a rule, to be preferable to thick ones. If the piston rings are gummed up they may often be made free with a little petroleum, and worked round by hand. There is much less liability to gas leakage, at the joints of the rings, if they are divided by a Z-shaped split instead of a straight cut.

Where low first cost is not an object, as elsewhere

remarked, instead of using snap rings, pistons can be recommended, built up with followers and rings, as they make a much better fit and the compression is improved in proportion.

Knocking in the Cylinder.—This often arises from premature firing of the charge before the end of the compression stroke is reached, thus throwing a greater pressure than usual on the piston before it commences the power stroke, and causing a jar or knock as the crank turns the dead centre.

It may also arise from late ignition, a mis-fire, the piston rings being loose, broken, or gummed up, improper or insufficient lubrication, or from ridges or irregular wear in the cylinder. The engine may also thump from too great a supply of gas; this may be ascertained by reducing the gas supply gradually.

Knocking in the Engine generally.—In addition to defects in the cylinder, etc., knocking or pounding may be caused at the end of the stroke when the crank is on the dead centre, from wear on the connecting-rod bearings, or from their not being keyed up tight enough.

Knocking may also arise from the key of the flywheel becoming loose, the crank-shaft or cross-head being out of line, from the axes of the journals

not being parallel, or the bearings requiring adjustment or lubrication. Worn valves will also cause knocking.

To secure economy, it need hardly be said that all the working details of the engine should be kept in the highest state of efficiency, and even small adjustments should not be neglected.

Governor Gear.—For regulating the amount of gas admitted to the cylinder and apportioning it to the load on the engine a variety of methods are used, the chief of which are—

(1) Entirely cutting off the supply of gas for a certain period, according to the speed of the engine ; (2) by throttling the supply—and reducing the quality of the charge—through the gas-admission valve ; (3) by regulating the amount of the explosive charge admitted ; (4) by keeping the exhaust valve open.

The first two are the plans chiefly employed, and for this purpose a large variety of regulators are used, such as centrifugal-ball or rotary governors, pendulum or inertia governors, weighted levers, dash-pots, etc.

The writer can speak well of the method (1) of cutting off the supply of gas entirely when the speed of the engine is too high, as air is then only admitted, whilst if the gas supply be only throttled, too weak a

charge for firing may be admitted, and the gas be wasted, or "back-firing" may ensue.

Practically the same effect as No. 1 is secured by 4, viz. keeping the exhaust valve open, as the vacuum in the cylinder is thus destroyed, and no fresh gas enters till the exhaust valve is closed, and many employ this method.

We have recently seen a governor gear in which the centrifugal and "hit-and-miss" principles were combined ; it worked well and appeared very reliable under varying loads.

To ensure extreme sensitiveness to varying loads, centrifugal governors are now sometimes mounted on ball-bearings.

Some makers of modern engines prefer governing by throttling the amount of the explosive mixture admitted to the cylinder, the quality of the mixture of gas and air remaining constant, and it is claimed for this arrangement that the strength of the impulse is thus always in proportion to the load on the engine.

It is beyond our province to enter into the different forms of governors here, but whatever form of gear be selected, it is important that it be rapid and positive in its action and free from mechanical complications, as should the joints, etc., stick or be bent the governor will "hunt," and an accident may occur.

All governors should be capable of adjustment as regards speed when the engine is running.

Classification of Various Methods of Governing.—

Hit-or-miss principle (1) shutting off gas supply ; (2) opening or closing exhaust ; (3) shutting off igniter ; (4) disengaging valve shaft.

Various impulse methods : (1) throttling gas supply ; (2) throttling charge of gas and air ; (3) varying the point of ignition.

In cases where gas or oil engines are fitted with electric ignition, they are sometimes regulated by the governor being connected with a switch, which automatically cuts the current off from the igniter when the limit of speed has been passed, and the charge is not exploded till the revolutions of the engine are reduced to the proper speed when the switch closes and the igniter again comes into operation.

A similar result may be attained also by varying the point of ignition, but both of these methods are not very economical.

Speed of Engine and Number of Explosions.—It being important that the engine should run at its proper speed, its revolutions should be tested every few weeks. This can readily be done by a speed recorder acted on by the revolutions of the crank shaft.

With the "Otto" cycle and the engine at full power, the explosions should be one-half the revolutions, and should this not be so, something is wrong with the working. The exhaust is the best point to count the explosions.

Piston Speed of Gas Engines.—The piston speed of gas engines is usually from 600 to 900 feet per minute.

The revolutions should not exceed about 600 per minute, as it has been found that after this speed the connecting-rod bearings become rapidly damaged, and there is a difficulty of getting rid of the exhaust.

Within certain limits, however, the higher the speed of the engine the better the results.

Hot Bearings.*—Heated bearings may arise from a variety of causes, such as—

(1) Bearings of insufficient area for the pressure or strain put on them; (2) engine running at short centres with a tight belt; (3) bad-fitting or seamy shaft; (4) bearings screwed up too tight; (5) insufficient lubrication, improper or bad oil; (6) dust or dirt in the bearings, oil grooves too shallow or oil-holes stopped; (7) bearings will also stretch and

* "A Handbook for Steam Users," (7th edition). M. Powis Bale.

pinch the shaft from being allowed to run slack, or get out of line or level; (8) from oil-boxes or lubricators being or becoming air-tight, and preventing the proper flow of the oil; (9) from the axes of all the journals not being parallel, or from the shafts not bedding evenly on the bottom of the bearings; (10) from the engine being overloaded.

Hot Crank-pin Bearings.—More particularly with engines in which the connecting-rod is arranged to work on to a crank pin, considerable trouble is often experienced through the bearings heating.

This may arise from their being poorly fitted, from requiring adjustment, from want of proper lubrication, or from the bearings being made too thin, sufficient metal not being provided to carry off the heat engendered from working when the bearing was slightly out of order.

Apparently well-fitted bearings may heat from another cause, and one that has puzzled a good many in detecting, and that is from the connecting-rod being out of line.

To detect this, take the connecting-rod out of the cross-head and key it up tightly on the crank pin. Now move the rod up and down, and see that it drops truly into the bearing on the cross-head; if it does not you will know it is out of line, and should

be overhauled and adjusted at once, as the bearing will never run cool under these conditions, it being very much strained, and the area in contact with the crank pin being largely reduced.

If on examination you find the bearings are wearing bell-mouthed, you may conclude it arises from the last-mentioned cause.

A similar trouble may arise with engines in which a sweep crank is used, but it is usually not so pronounced.

If the bottom of a bearing is scored at its one end, and at its top at the other end, it shows that it is out of alignment.

Pre-ignitions in gas or oil engines will rapidly cause the crank pin to heat.

Examining Gas or Oil Engines.—Before examining an engine with a light, care should be taken that the combustion chamber is free from gas mixture. This can be done by turning the engine round a few times. Of course, the ignition light should be put out and the gas-supply cock closed. It is more or less dangerous to look down the chimney when the engine is running.

Cleaning a Gas or Oil Engine.—This duty should be regularly and thoroughly performed at stated

intervals, as should the products of combustion, carbonized oil, etc., be allowed to accumulate, large loss of power may result. Practically the whole engine should be taken to pieces, and the cylinder, piston, valves, governors, levers, exhaust pipe bearings, etc., taken seriatim and thoroughly cleaned and adjusted.

In getting rid of the hard carbonized oil from the working parts copper tools should be used, and when the parts are thoroughly cleaned they should be rubbed over with kerosene. If nuts are set fast they should not be forced, but be loosened with kerosene. By using a little powdered plumbago and oil on the screw threads setting may be prevented.

Should the piston or cylinder cover nuts seize, a good plan is to put a ring of red-hot iron round the nuts, which causes them to expand slightly, and so eases them. In the case of spray-making oil engines it is very important that the spray holes are kept clear.

Depending as it does on the nature of the charge, no fixed rules can be made as to how often an engine requires cleaning.

Two-cycle Gas Engines.—Although most gas engines are built on the four-cycle system, some—more particularly large engines—are now constructed

on the two-cycle principle—that is, they work with two impulses every revolution, after the same fashion as a steam engine.

Consequently steadier running is thus obtained, and the same power can be developed by a smaller engine than where the four-cycle system is in operation. We look for considerable development in this connection, as amongst other advantages of this system lighter flywheels can be used; consequently, the friction on the bearings is reduced, and at the same time exhaust valves—which often give trouble—can be done away with.

In one engine of recent construction the cylinder is charged by a pair of double-acting pumps—one for gas and one for air—which are accurately proportioned in size, so as to admit the correct explosive mixture alternately to the back and front end of the cylinders, and the products of combustion are allowed to pass away through ports in the cylinder casting, instead of through a valve.

A difficulty found with high speed—impulse every revolution—engines is in getting rid of the hot gases of the exhaust, which rapidly damage the valves. To minimize this, valves made of pure nickel have been introduced, we believe, with some success.

With very high speeds not only is the wear of the engine increased, but sufficient time is not given for

the complete combustion of the charge, and the temperature of the discharged gases in the exhaust is raised ; consequently, the favourable effects of increased speed are sometimes nullified.

Gas Engines for Electric Lighting.—Where engines are employed for electric lighting, extreme steadiness in running is an absolute necessity, consequently the speed of the engine should not, under ordinary working conditions, vary more than about 1 per cent.

To secure a steady light with gas or oil engines, the practice has been to flywheel the dynamo, as the speed of ordinary engines sometimes varies as much as $7\frac{1}{2}$ per cent. Of late, however, the constructional details of the best gas engines used for this purpose have been so considerably improved that flywheeling the dynamo is now no longer necessary.

This constant speed has been largely secured by increasing the diameter and weight of the flywheels, together with an improved method of direct balancing, the balance being fitted to the crank, instead of to the rim of the flywheel, which is usually the case with ordinary engines. Very sensitive governor gear is also, of course, necessary.

For large powers and extreme regularity, two, three, or four-cylinder engines can be recommended.

Some large engines of the vertical type have

recently been constructed, and it is claimed for this arrangement that vibration is thus reduced to a minimum, making them especially suitable for coupling direct on to the dynamo.

Supplementary electric barring engines are now often used for starting, or a charge of naphtha vapour is sometimes employed for the same purpose where producer gas is used.

Compound Gas and Oil Engines.—As illustrating the development of gas engines for large powers, it may be mentioned that an engine has very recently been constructed in which the principle of compounding has been introduced.

The engine is made with three cylinders—two high pressure and one low—and the pistons are operated from three cranks, the two high pressure or explosive pistons acting together. The distribution is by means of a single rotary valve, which revolves at one-fourth the speed of the engine, and is balanced against the force of the explosions.

In this engine there are two impulses for each revolution. The governor is fixed on the crank shaft, and operates through the medium of an adjustable throttle valve.

The cylinders are scavenged by means of charges of cold air, which follow the burnt gases.

As the principle of compounding is undoubtedly of the highest commercial value, we look forward with interest for further development in this connection.

Gas Engines using Producer Gas v. Steam Engines.

—There can be but little doubt that large modern gas engines, using a good uniform quality producer or blast-furnace gas free from impurities, compare very favourably on the score of economy with the steam engine. This arises from the cheapness of the fuel in the first place, from the superior calorific value of the gas over steam, and the more efficient utilization of the heat in the gas engine.

The use of gas also gets rid of the dangers arising from high-pressure steam, the loss from its condensation, and glands and packing are also done away with. On the other hand, where extreme steadiness of running is required—as in electric lighting—the consensus of opinion is still generally in favour of steam.

Another drawback to the employment of gas engines for many purposes is that they must be run at one uniform speed, and they cannot be reversed. The cost of cylinder lubrication for gas engines is also greater than for steam engines of equal power, but notwithstanding these drawbacks there is undoubtedly a great future for them.

The utilization of waste blast-furnace gas for power purposes has of late years been largely extended, many of the initial difficulties having been successfully overcome, and still further great development in this connection will doubtless be made.

One of the original difficulties arose from the larger amount of dust with which they are charged, but several successful systems of purification are now in use, the gas after purification and cooling usually passing to a gas-holder, and thence to the engine.

Owing to the low calorific value of blast-furnace gases, large engines and high compression of the charge are necessary for its use, and engines have now been successfully constructed up to some fifteen-hundred horse-power. These are usually fitted with electric ignition, which has proved itself to be especially well adapted for firing gases of low value.

CHAPTER V

OIL ENGINES

Oil engines—Vaporizers—Insufficient vaporization—Methods of ignition—Electric igniters—Low-tension ignition—Magnetoelectric ignition—Dynamo igniters—Igniter points—Insulating electric igniters—Failures of electric ignition—Oil engine governing—Cylinder lubrication of oil engines—Bumping in cylinder, etc.—Starting an oil engine—Failures of oil engines—Engines refusing to start—Engine losing compression—Oil pump and valve—Portable oil engines—Piston speed of oil engines.

Oil Engines.—More particularly in countries or districts where coal or gas is not readily available, oil engines—or perhaps, more correctly speaking, oil-vapour engines—have been introduced to a considerable extent.

As regards cycle of operations and construction, most of them do not differ very materially from ordinary “Otto” cycle gas engines, and some gas engines, by a slight change in the valve mechanism and the addition of a vaporizer, could be used for either gas or oil.

Many of our remarks on gas-engine management will therefore apply more or less well to oil engines.

Unlike gas engines—which have a constant supply of gas made for them—oil engines have to make their own as required, and it may be of interest to briefly note how this is done.

The oil almost always used is petroleum; also its varying forms, such as light oil, naphtha, gasoline, benzoline, petroleum spirit, etc.

Some of these latter, however, are only used to a comparatively limited extent in stationary engines, as they are more or less dangerous, and require careful handling.

Oil engines of the usual construction are more liable to pre-ignitions than gas engines; especial care should therefore be taken as to the amount of compression used, also the ignition and water-cooling arrangements.

Before oil engines could be pronounced a commercial success, many difficulties have had to be overcome.

This has arisen chiefly through the constantly varying constituents of the oil itself, which differs largely in the amount of hydro-carbons it contains; also in density, flash point, calorific value, etc. (see Table, p. 101).

Consequently different oils require more or less different treatment before they can be successfully converted into oil gas, or vapour ; hence the difficulties, more particularly with the heavier oils.

The problem engineers had to face was the construction of a vaporizer or other system that would prepare successfully the heavy petroleum oils, and although these difficulties have recently to a great extent been overcome, ample scope still remains for further improvements, as many engines even now cannot successfully use heavy oils, and the general efficiency of oil engines as a rule is not so high as gas engines.

An exception to these remarks must, however, be made in favour of an engine recently introduced—the Diesel—which is now running under varying conditions, and using with success the crudest and commonest oils.

The four chief features claimed for this engine are—

(1) “ The attainment of the temperature necessary for ignition by mechanical compression alone, so that an injected flame, incandescent tube, electric spark, or other extraneous igniting device, is abolished.

(2) “ The injection of the fuel after compression has been completed, and only during the first part of the working stroke, the compression in the working

cylinder being that of air alone. Thus no explosive mixture exists in the cylinder before the beginning of the working stroke, and no premature ignition is possible.

(3) "Another distinctive feature is that the fuel is injected gradually into the highly heated air, each drop of the spray burning immediately and quietly, so that no explosion takes place, while the period of injection and the quantity injected are delicately regulated by the governor, in accordance with the demand for power.

(4) "Thus, the governing is effected within the four-stroke cyclic period of thermo-dynamic action, and every such period has its working stroke."

The products of combustion are periodically scavenged by a rush of fresh air from an air reservoir, which passes through the cylinder into the exhaust.

As the charge in this engine is fired by the high rate of compression to which the air is subjected, a starting apparatus is required. This is operated by means of compressed air, which is stored in a steel chamber, and admitted to the cylinder by a special valve, the oil inlet valve at the same time being out of action. After a few revolutions, the oil valve is thrown into operation, and the engine commences to work.

The success of this engine, both mechanically and commercially, solves in its working a scientific problem of automatic internal combustion that has long interested and puzzled both scientists and engineers, and we look forward to great developments in this connection.

Vaporizers.—The vaporizer is a heated chamber, which is in use on the majority of oil engines for transforming the charge of oil into vapour before being mixed with air, and passed into the cylinder or combustion chamber.

Each charge of oil is vaporized as required, and their action must not be confused with that of the carburetter, which is largely employed on automobiles.

This, by passing air through or over a quantity of oil, carries off a certain amount of rich vapour, which is stored, and, after receiving a further supply of air, is fired in the cylinder in the usual way.

Vaporizers vary considerably in their construction and methods of working.

In some the oil strikes the air as it enters; in others a pump forces a jet of oil against the side of the air-pipe or the compression space, and is thus broken up into spray and mixed with the hot air, which rapidly vaporizes it.

The proportions of the charge of oil and air are regulated by suitable valves.

Although the design and arrangements of apparatus for vaporizing the oil—before it can be mixed with air and exploded in the cylinder—vary considerably, they may be roughly divided into two classes:—

(1) Spray-makers and (2) non-spray-makers, and these, again, into three classes:—

(a) A vaporizer, in which the oil is broken up into spray and completely mixed with air in a hot chamber before passing into the cylinder.

(b) A vaporizer or chamber containing compressed and heated air, into which oil is injected and immediately vaporized.

(c) A vaporizer kept at a very high temperature into which oil is admitted in small quantities, and is converted into vapour, and some advantages are claimed for all these arrangements.

Vaporizers of the ordinary type are usually heated by an automatic lamp or Bunsen burner fed with oil from an independent reservoir, and it is important in order to secure efficient working that they be kept to a constant heat.

In ordinary engines, oil is generally supplied to the vaporizer by a pump, or by gravitation.

The former is to be preferred, being more certain in its action.

The pump should be made of gunmetal, and arranged to deliver exact quantities of oil.

Some makers arrange two suction and two delivery valves, with the object of giving increased certainty of action. A difficulty sometimes, however, arises in working oil pumps in keeping them clear, owing to the small valves which are necessary, and in keeping the gland round the plunger tight.

Some engineers rely on the suction stroke for drawing the oil and air into the vaporizer, but this plan is not always reliable.

Some makers use one automatic lamp only for heating both the vaporizer and ignition tube, and keep it constantly burning, and it is claimed for this arrangement that as the vaporizer is not dependent on the varying explosions in the cylinder for maintaining its temperature, the engine will work equally well under light or heavy loads, and if the engine is stopped for a short time the vaporizer does not require re-heating.

All vaporizers and lamps should be thoroughly cleaned about every three days, or oftener, with the heavier oils. The vaporizing chamber should be rubbed out with paraffin.

A simple and efficient form of vaporizer is one which is kept to a very high temperature, and

which fires the charge. During the out-stroke of the piston the oil is vaporized, and compressed on the in-stroke, and finally fired by the heat of the vaporizer itself, when the crank reaches the back centre.

The end of the vaporizer attached to the cylinder is water-jacketed, as well as the cylinder itself. This vaporizer is heated in the first instance by means of a lamp or burner, and afterwards kept hot by the heat from the explosions of the charge.

An early difficulty found in this type of vaporizer was that it would not allow the engine to run any considerable length of time under a light load, owing to the cooling of the vaporizer from the number of explosions being thus reduced.

Insufficient Vaporization.—If the oil is insufficiently vaporized, owing to the vaporizer not being hot enough, a portion of it may be carried over into the cylinder and give trouble in starting, and vapour may show itself at the air inlet from late ignition of the charge, or if the gas valve is not tight on its seat.

If too much oil is fed to the vaporizer it may not be entirely vaporized, and will render the engine more difficult to set in motion.

Methods of Ignition. — The methods usually

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employed to ignite the charge in oil engines are by means of: (1) an electric spark; (2) a heated tube or naked light; (3) a red-hot vaporizing chamber; (4) by high mechanical compression of the charge.

Electric spark igniters can be operated by coil batteries or accumulators, magneto or dynamo apparatus. The constant renewal necessary with batteries to enable them to maintain a sufficient current to give off a strong-enough spark, has caused them to give way to a large extent in favour of magnets or dynamo ignition and the last three methods.

Accumulators will give a steady current for a considerable period, but, of course, require re-charging from time to time. Where facilities exist for this their action can be relied on. A magneto, with a stationary armature, also gives very good and constant results.

Where a very strong spark is required, a dynamo apparatus, with a revolving armature, can be recommended.

Electric Igniters.—Electric igniters are well adapted for oil engines, being safe, and the point of ignition can be readily altered and controlled, but they are rather more liable to disarrangement than with a heated tube.

The two forms of electric ignition generally used

are known as the "make and break," and the "jump" spark.

If electric ignition be used, before starting the engine, it should be tried, to see that it gives out a good stout spark, and the usual point of ignition be marked on the piston or flywheel, as it will save a great deal of trouble when the igniter is altered or adjusted.

A considerable difference of opinion appears to exist as to the best form of electric ignition. Some engineers prefer to use an accumulator or battery with a high-tension coil ; others, including the writer, consider, on the whole, that a magneto or dynamo arrangement is to be preferred, being more certain in their action, and less liable to disarrangement from leakage or short circuits, as no battery, etc., is required, the current being produced by the mechanical power of the engine itself.

Although there are some drawbacks to the use of electric igniters, as already remarked, they possess various advantages, such as that the small ports and passages necessary to tube ignition are got rid of, and the ignition takes place right in the combustion chamber.

At the same time, the point and time of ignition is readily altered and adjusted, and ignition and timing valves can be done away with.

It need hardly be said that whatever form of electric ignition be used, its success depends very largely on its proper management, and the correct supply of current to make a good hot spark.

For instance, if the current be too strong, the contact points will rapidly deteriorate, and, if too weak, the firing will be irregular.

In cases where sparking coils are used, an efficient condenser should be fitted, to regulate the current, and contact tips of pure platinum, or platinum iridium alloy, can be recommended. The contact points for magneto igniters are frequently made of soft iron.

A cam arrangement is often used for breaking the circuit, and producing a spark in the combustion chamber.

Near the end of the compression stroke the igniter cam completes the circuit, by bringing the igniter terminals into contact, and at the correct moment releases them, and they fly apart and break the circuit, a spark being thus produced, which fires the charge.

On large engines, electric igniters should be arranged in duplicate, in case of a breakdown.

Low-tension Ignition.—Speaking generally, for stationary engines the writer prefers a system of

ignition which produces alternating currents at a low tension, as the insulation and general management is easier than with high-tension systems.

Magneto-electric Ignition.—This form of ignition, although sometimes a little complex in its construction, is more certain in its action than the battery and coil system.

An improved form of apparatus has recently been introduced for both gas and oil engines with very satisfactory results. Its action is briefly as follows:—The generator for producing the spark is made up of powerful horse-shoe magnets, a stationary armature, and a soft-iron envelope, which has an alternating motion, and works between the magneto and the armature.

Instead of cutting the lines of force and producing the spark in the usual way by revolving the armature, the reciprocating movement given to the soft-iron envelope uncovers the iron portion of the armature, which causes a momentary electric current and spark.

The machine is mounted over the cam shaft of the engine, which revolves and a cam raises a lever, which, by means of a rod, breaks contact at the moment a spark is required. This arrangement admits of very accurate timing.

It is important that the magneto used be amply powerful for the work.

Another form of magneto generator operates as follows:—"Within a circular multipolar magnet is carried a star-shaped armature, having an arm for each pole of the permanent magnet, with an induction coil wound upon each arm. This armature is simply vibrated about the centre sufficiently to make the armature pass their respective poles, producing current in their primary windings, which is by the secondary windings raised to such a potential as to furnish a good spark with a "make-and-break contact," even when the armature is vibrated by hand."

Dynamo Igniters.—A considerable variety of dynamo igniters operated both with and without coils are in use, and as a rule may be pronounced as more certain in their action than batteries or accumulators, giving a stronger and better spark.

For fixed engines an enclosed two-pole drum armature dynamo, series wound, will answer very well without an induction coil, as a good spark is regularly given off when the circuit is broken.

It need hardly be said that it should be thoroughly well made, owing to the speed at which it runs, especial attention being given to the bearings—which should be long—and to their lubrication.

The commutator should be extra wide, and the brushes of carbon, and of ample carrying capacity. The brush holder should be strong and well insulated, and the brushes should press firmly, but not heavily, on the commutator.

If the brushes should have insufficient contact, sparking will result, and if the pressure is too much the commutator surface is unduly worn. The surface of the commutator should be kept smooth.

Sparking may also be caused by defective brushes, commutator, or armature coil. To secure a stout and even firing spark, it is important that the speed at which the dynamo runs is uniform and correct.

For ignition purposes an apparatus known as a dynamo coil is also used. This is a combination of an ordinary series-wound dynamo, and an induction coil, and it is claimed for this arrangement that a steady flow of "stout" sparks—as from the induction coil—is obtained from it, and with much greater certainty than when batteries or accumulators are employed.

What is required for this form of ignition for gas and oil engines is a dynamo which will give a constant and non-varying voltage and is self-governing at various speeds. It should preferably be enclosed, and in all cases be shunt wound for this purpose. It is often used in conjunction with an accumulator, although this latter is not an absolute necessity.

Igniter Points.—Igniter points should be short and thick. If too thin, they may become heated to incandescence, and cause pre-ignitions.

Insulating Electric Igniters.—For this purpose mica insulation bushes can be recommended.

Failures of Electric Ignition.—Electric igniters fail from a variety of causes, such as (1) wire broken in circuit ; (2) terminals too thin and overheated, or at an incorrect distance apart ; (3) wrong adjustment of contact breaker ; (4) loose or corroded connections ; (5) short circuits between terminals or battery, etc. ; (6) a weak or defectively constructed battery or accumulator. “Jump spark” igniters—which are largely used in motor cars from other reasons than those already given, such as (7) an accumulation of carbon bridging the terminals and causing a short circuit ; (8) insulation of the plug defective, or plug damp ; (9) terminals too near to ironwork of engine, etc. An accumulation of carbon or partial insulation is often caused by too much lubrication, or the use of an improper oil. The plugs, etc., should be frequently cleaned. (10) A sparking plug made of bad or unsuitable material is also the cause of many failures ; (11) in a magneto igniter, from the magnets not being sufficiently powerful ; (12) in a dynamo

igniter, from defective brushes, commutator, armature, etc.

Oil Engine Governing.—The system of governing perhaps most generally used is one in which the governor controls the oil and vapour or air valves, and thus regulates the charge according to the load on the engine. Some makers, however, regulate the oil supply by means of a by-pass valve, and others by keeping the exhaust valve open, and so stopping the supply of oil through the inlet valve. Advantages are claimed for each method.

The writer has found the first one very effective, particularly when running under a full load. When a by-pass valve is used, the explosions are not cut off, but part of the oil supplied by the pump is allowed to flow back to the oil tank, which is usually formed in the base of the engine itself.

Cylinder Lubrication of Oil Engines.—Owing to the rapid decomposition of the lubricating oil in oil-engine cylinders, it is very important that an oil is selected which does not vaporize or carbonize easily and leave much residue, or trouble will arise from the piston rings sticking. A positive feed drop and sight-feed lubricator should be employed, and no more oil used than is absolutely necessary. For some reason

not readily explained, oil engines generally give more trouble in this connection than gas engines. One suggestion is that the hydro-carbon vapour of an oil engine affects the lubricant in a different manner to the explosive mixture of a gas engine.

Bumping in Cylinder, etc.—If the cylinder is in good condition, and a bumping noise is heard when working at full load, it may arise from too much oil being supplied to the engine, which should be regulated accordingly.

Starting an Oil Engine.—In starting an oil engine, a regular routine of operations should be gone through, but as the methods employed for vaporizing, ignition, etc., vary largely, it is impossible to formulate any set rules. In engines where ignition tubes are used and vaporizers are heated by lamps, care should be taken, in the first place, that each tank—which should be fitted with gauze strainers and gauges—is perfectly clean and full of oil, the valves clean, and the working parts of the engine well lubricated.

Before starting, the oil pump should be tested by hand. The lamps and ignition apparatus should also be thoroughly cleaned, and the oil pump tried. The lamp or lamps for ignition tube and vaporizer should

then be lighted, and when the ignition tube is heated to a cherry red, and the vaporizer is also thoroughly heated, the engine is ready to start. To save time, the lamps can be lighted before commencing to oil the engine. In starting by hand, the compression in the cylinder can be relieved by holding the exhaust valve open.

Failures of Oil Engines.—In addition to some of the causes of failures in ordinary gas engines already mentioned, faults in the vaporizers and ignition arrangements are a fruitful cause of failures in some oil engines, such as insufficient spraying and mixing of the oil and air, too cool a vaporizing chamber, oil pump clogged, etc., and in the case of electric firing, from the ignition apparatus being out of order, the vapour valve, vaporizer, or lamp being clogged or dirty, etc.

Engines Refusing to Start.—Engines will sometimes refuse to start, even if the engine is in order. This will probably arise either from too much oil in the vaporizer, improper mixture, too much air, too early firing of the charge, or from insufficient speed to overcome the compression. Should the engine slow down after starting, a little extra oil should be pumped by hand. Examine all valves, and see that they act

at the right time, or if dirt prevents them closing properly.

Engine losing Compression.—Should the engine lose its compression, the exhaust valve should be examined and cleaned ; also the air and vapour valves and lamp. Should this not have desired effect, the fault probably arises from the piston rings, which should be adjusted.

Oil Pump and Valve.—These should be carefully cleaned and adjusted, so as to supply the correct amount of oil to suit the average load on the engine. The deliveries of the oil should be clear and decisive. If the oil is allowed to leak or dribble into the vaporizer when not required, a serious loss may occur.

As they have to bear some pressure, the fittings of oil pipes are best sweated on. If the pump gives an irregular supply of oil, the governor gear will not work properly, and the speed of the engine will be irregular. The oil pipe from pump to vaporizer should have a gradual rise. Should the supply of oil have got too low in tank and the pump been allowed to draw air, it may be expelled by working the pump by hand and holding open the relief valve.

Portable Oil Engines.—A considerable variety of

portable oil engines are now made. In them the cooling water for cylinder is usually circulated by means of a small pump, and to increase the steadiness of running, the crank shaft should be balanced and the travelling wheels be of ample width.

Piston Speed of Oil Engines.—From 450 feet to 850 feet per minute.

CHAPTER VI

RULES, TABLES, ETC.

Horse-power—Nominal horse-power (N.H.P.)—Indicated horse-power (I.H.P.)—Brake horse-power (B.H.P.)—Rule for indicated horse-power—Rule for brake horse-power—Thermal efficiency (Fowler)—Mechanical efficiency—Specific heat of coal gas and air—Gas engine tests (Emmott)—Battery for ignition spark—Coal gas—Analysis and calorific value of various gases—Calorific power of various fuels in British thermal units—Weights and specific heat per cubic foot of various gases (Roberts)—Pressure of atmosphere—Chemical composition, heating power, and theoretical evaporation of petroleum fuels (Urquhart)—Properties of petroleum and shale oils used in Britain (Robinson)—Lowest legal flash point—Whitworth gas and water pipe threads—British and metric equivalents.

Horse-power.—As some confusion exists amongst users as to the various expressions of horse-power (H.P.), it may be stated that a horse-power is the quantity of work equivalent to the raising of 33,000 lbs. through one foot in one minute, or to equivalent motion against resistance.

Nominal Horse-power (N.H.P.) is a more or less

obsolete term used by manufacturers to denote the size of the engine.

Indicated Horse-power (I.H.P.) is the power produced in the cylinder, from which must be deducted the power required for driving the engine itself.

Brake Horse-power (B.H.P.), called also **Actual Horse-power**, is the net effective power given off from the driving pulley of the engine, and this form of horse-power is the one for which a guarantee should be obtained from manufacturers by users.

Rule for Indicated Horse-power:—

Let i = number of explosions per minute.

A = area of piston in square inches.

L = stroke in feet.

P = mean pressure in pounds per square inch

$$\text{I.H.P.} = \frac{LiAP}{33,000}$$

Rule for Brake Horse-power:—

Let S = spring-balance readings in pounds.

W = load on brake, including hook and unbalanced part of rope, in pounds.

D = diameter of brake wheel measuring to the centre of the rope in feet.

R = revolutions of engine per minute.

Then B.H.P.

$$= \frac{(W - S) \times DR}{33,000}$$

$$= 0.0000952(W - S)DR.$$

Thermal Efficiency (Fowler).—Theoretical thermal efficiency of gas engine = $1 - \frac{C_p}{C_v} \cdot \frac{T_5 - T_1}{T_4 - T_3}$

When C_p = specific heat of charge at constant pressures.

C_v = specific heat of charge at constant volume.

T_1 = temperature of exhaust gases.

T_3 = temperature before ignition.

T_4 = temperature maximum.

T_5 = temperature at end of expansion.

Mechanical Efficiency.—Mechanical efficiency is the ratio of the useful work done to the total work expended.

If M.E. = mechanical efficiency,

W F = work lost in friction,

then $M.E. = \frac{B.H.P.}{I.H.P.}$ and $W F = I.H.P. - B.H.P.$

In practice a single-cylinder single-acting engine may have a mechanical efficiency of 0.88, but for purposes of design it is usual to allow for 0.85 only.

For tandem-scavenging engines 0.75 is a usual allowance.

Specific Heat of Coal Gas and Air.—Calculation of specific heat of mixtures of coal gas and air:—

$$\left. \begin{array}{l} \text{Specific heat at constant} \\ \text{volume} \end{array} \right\} = \frac{R \times 0.168 + 0.286}{R + 0.48}$$

$$\text{when } R = \frac{\text{volume of air}}{\text{volume of gas}}$$

$$\left. \begin{array}{l} \text{Specific heat at constant} \\ \text{pressure} \end{array} \right\} = \frac{R \times 0.237 + 0.343}{R + 0.48}$$

Gas Engine Tests (Emmott).—In making a complete trial, the following observations should be made:—

Temperature, pressure, and cubic feet of gas through meter; pounds of jacket water, inlet and outlet temperatures in degrees Fahr.; revolutions of engine by counter; explosions by special counter; spring-balance readings and load on brake; height of barometer; temperature of exhaust by electrical pyrometer; continuous calorimetry of gas by Junker's calorimeter; samples of gas for analysis; indicator diagrams.

Battery for Ignition Spark.—A battery often

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used for generating the electric spark is charged as follows:—

Bichromate of potash	8 ozs.
Sulphuric acid	6 ozs.
Water	80 ozs.

Coal Gas.—

Analysis of coal gas.	1	2	3
Hydrogen	51·8	36·1	48
Carbon monoxide	9·1	6·8	8
Marsh gas	31·8	37·8	36
Olefines (ethylene, etc.)	5·2	16·4	3·8
Nitrogen	2·1	2·9	4·2

1. London gas (Wight). 2. Cannel gas. 3. Average. The average gas (3) has a calorific power of 11,540 B.T.U.

Analysis and Calorific Value of Various Gases—

Volume per cent.	Coal gas.	Dowson producer gas from anthracite.	Mond producer gas from bituminous fuel.	Liemens producer gas.
Hydron (H)	48·0	18·7	24·8	8·6
March gas (CH ₄)	39·5	0·3	2·3	2·4
Olefines (Cn H _{2n})	3·8	0·3	Nil.	Nil.
Carbonic acid (CO ₂) and Oxygen	0·7	6·6	12·9	5·2
Carbonic oxide (CO)	7·5	25·1	13·2	24·4
Nitrogen (N)	0·5	49·0	46·8	59·4
Total combustible gas	98·8	44·4	40·3	35·4
Air required for combustion per 100 vols. gas	581	113	112	101
Calorific value per cubic foot, British thermal units	685	160	155	135
Pounds of coal used in producer per I.H.P. hour	(cub. ft.) 22	Anthracite 1·0	Bituminous slack 1·03	—

Calorific Power of Various Fuels in British Thermal Units—

Combustible.	Calorific power.	Evaporative power from and at 212° F.	Carbon value.
Carbon, burned to carbonic acid	14,500	15'00	1'000
Carbon, burned to carbonic oxide	4,450	4'61	0'307
Charcoal from wood ...	12,000	12'4	0'827
Coke	13,000	13'45	0'896
Coal, bituminous, average ...	14,000	14'48	0'965
Coal, anthracite, average ...	15,000	15'52	1'035
Coal, Welsh, average ...	14,800	15'31	1'021
Creosote or tar refuse ...	17,400	18'00	1'199
Naphtha refuse ...	19,200	19'86	1'324
Petroleum, average ...	20,000	20'68	1'379
Hydrogen	62,060	64'19	4'280
Coal gas, average ...	21,000	21'72	1'448
Natural gas (Pennsylvania) ...	26,000	26'89	1'793
Olefiant gas	21,343	22'08	1'472
Marsh gas	23,513	24'32	1'621
Block fuel	15,000	15'52	1'035
Sulphur	4,000	4'138	0'276

Weights and Specific Heat per Cubic Foot of Various Gases (Roberts)—

	Lbs. per cubic foot.	Specific heat.
Marsh gas	0'0447	0'470
Olefines	0'1174	0'332
Hydrogen	0'00559	2'406
Carbon monoxide	0'0783	0'173
Nitrogen	0'0783	0'173
Carbon dioxide	0'1060	0'171
Oxygen	0'1060	0'155

These weights are for gases when at an atmospheric pressure of 14·7 lbs. per square inch, and a temperature of 32° Fahr.

Pressure of Atmosphere.—Pressure of atmosphere in lbs. per sq. in. = height of barometer in ins. + 0.491.

Pressure of gas in pounds per sq. in. = height of water gauge + 0.0361.

Weight of 1 cub. ft. dry air in pounds at 32° Fahr. and 14.7 lbs. per sq. in. = 0.08073.

Weight of 1 cub. ft. coal gas in pounds at 32° Fahr. and 14.7 lb. (average) = 0.03348.

Chemical Composition, Heating Power, and Theoretical Evaporation of Petroleum Fuels (Urquhart)—

Description.	Specific degree of 32° Fahr.	Carbon.	Hydrogen.	Oxygen.	Heating power in Br. Th. Units.	Evaporation in pounds of water, from and at 212°.
		p.c.	p.c.	p.c.		
Pennsylvanian heavy crude oil ...	0.886	84.9	13.7	1.4	20736	21.48
Caucasian light crude oil ...	0.884	86.3	13.6	0.1	22027	22.79
Caucasian heavy crude oil ...	0.938	86.3	12.3	1.1	20138	20.85
Petroleum refuse ...	0.938	87.1	11.7	1.2	19832	20.53
Good English coal average ...	1.380	80.0	5.0	8.0	14112	14.61

Properties of Petroleum and Shale Oils used in Britain (Robinson)—

Name of oil.	Colour.	Specific gravity at 69° Fahr.	Specific heat.	Flashing point.		Boiling point, Cent.
				Fahr.	Cent.	
Burning oils—						
American Royal Daylight ...	Light straw	0·811	0·47	76	24·5	144
American ordinary	Light straw	0·791	—	75	24	145
American Water-white ...	Colourless	0·780	—	108	42	150
American Tea Rose	Light straw	0·797	—	83	28·3	150
Russian ordinary (Russoline) ...	Light straw	0·824	0·43	82	27·8	151
Russian Lustre ...	Light straw	0·825	0·45	—	—	—
Broxburn Light-house ...	Light straw	0·810	0·44	152	66·7	165
Intermediate oils—						
American mineral sperm ...	Straw	0·833	—	—	—	195
Storror's Scotch gas oil ...	Reddish brown	0·843	—	—	—	195
Scotch intermediate shale oil ...	Clear brown	0·846	—	—	—	195
Light lubricating oil ...	Clear brown	0·853	—	225	107	195

Average analysis of "heavy" oil: carbon, 85 per cent. ; hydrogen, 15 per cent.

Average calorific value of oil: 20,000 thermal units per pound.

Lowest Legal Flash Point.—The lowest legal flash or ignition point of oils in England is 73° Fahr., but there is every probability that this will be raised. The lighter the oil the more rapidly it gives off

inflammable vapours, consequently the more dangerous it is. What may be termed the intermediate oils are generally to be preferred for general use.

Whitworth Gas and Water Pipe Threads.—Pipes having an internal diameter of $\frac{1}{8}$ in. have 28 threads to the inch; an internal diameter of $\frac{1}{4}$ in. and $\frac{3}{8}$ in. 19 threads to the inch; an internal diameter of $\frac{1}{2}$ in., $\frac{5}{8}$ in., $\frac{3}{4}$ in., and $\frac{7}{8}$ in., 14 threads to the inch, and all others from 1 in. to 4 ins. inclusive, 11 threads to the inch.

Internal diameter of pipe.	External diameter of pipe.	Diameter at bottom of thread.	Internal diameter of pipe.	External diameter of pipe.	Internal diameter at bottom of thread.	Internal diameter of pipe.	External diameter of pipe.	Diameter at bottom of thread.
$\frac{1}{8}$	.38	.34	1	1.74	1.63	2	3.0	2.88
$\frac{1}{4}$	.52	.45	1	1.88	1.76	2	3.12	3.01
$\frac{3}{8}$	.66	.59	1	2.02	1.90	2	3.25	3.13
$\frac{1}{2}$	.83	.73	1	2.16	2.04	2	3.37	3.25
$\frac{5}{8}$	.90	.81	1	2.24	2.13	3	3.48	3.37
$\frac{3}{4}$	1.04	.95	2	2.35	2.23	3	3.70	3.58
$\frac{7}{8}$	1.19	1.10	2	2.47	2.35	3	3.91	3.79
1	1.31	1.19	2	2.59	2.47	3	4.12	4.01
1	1.49	1.37	2	2.79	2.68	4	4.34	4.22
1	1.65	1.53						

British and Metric Equivalents.—Length :—

1 inch = 2.54 centimetres.

1 foot = 30.4799 centimetres.

1 yard = 0.914399 metre.

1 mile = 1.6093 kilometre.

1 chain = 20·1168 metres.

1 chain = 66 feet = 100 links.

1 mile = 5280 feet = 80 chains.

1 knot = 6080 feet.

0·39370113 inch = 1 centimetre.

$\left. \begin{array}{l} 39·370113 \text{ inches} \\ 3·280843 \text{ feet} \\ 1·0936143 \text{ yards} \end{array} \right\} = 1 \text{ metre.}$

0·62137 mile = 1 kilometre.

1 radian = 57·296 degrees.

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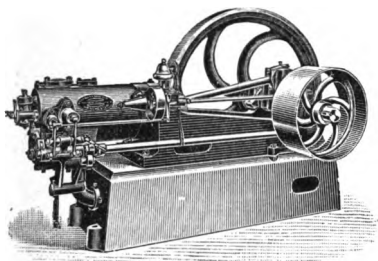
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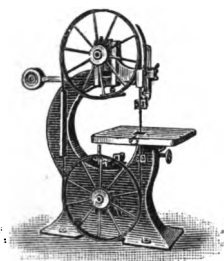
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